AN OVERVIEW OF SOLAR RADIATION DATA COLLECTION AND APPLICATIONS IN ALBERTA

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AN OVERVIEW OF SOLAR RADIATION DATA COLLECTION AND APPLICATIONS IN ALBERTA

RESEARCH MANAGEMENT DIVISION
Alberta Environment

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AN OVERVIEW OF SOLAR RADIATION DATA COLLECTION AND APPLICATIONS IN ALBERTA

by

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RESEARCH MANAGEMENT DIVISION
Alberta Environment

April 1985

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ABSTRACT

Existing sources of information on solar radiation data collection programs are compiled. Agencies and departments collecting the data are identified. The purpose of the data collection, measured variables and the frequency of measurements are noted, as is the availability of the data to other users.

Solar radiation measurements are made at 36 locations in the province. In addition to incoming solar radiation, net, photosynthetically active, and ultraviolet radiation are recorded occassionally for specific research needs.

1. INTRODUCTION

Solar radiation measurements are routinely made by several provincial government agencies in Alberta. These agencies were identified in the report, An Assessment of Collection and Handling of Climatic Data by Alberta Government Agencies (Hansen and Jones 1983). Solar radiation comprises a small portion of the total amount of climatological data collected in the province. The network of sites where solar radiation is measured is expanding as the need for viable, alternate energy sources, including wind and solar power, is explored.

Three agencies within the Alberta government have recently expressed a desire for increased access to solar radiation measurements. The Land Use Branch of Alberta Energy and Natural Resources identified the evaluation of the roles of wind and solar radiation in the evapotranspiration process as an urgent research need. The Resource Appraisal Section of the same agency requires a broader data base of parameters to evaluate agricultural potential. One parameter specifically required for this is solar radiation data. The River Forecast Centre of Alberta Environment is currently investigating the relationship between solar radiation and the snowmelt processes (Hansen and Jones 1983).

This report identifies existing data sources and research projects in Alberta utilizing solar radiation data. Current applications and uses of the data are presented. Specific objectives of this report include:

1. Identify which agencies and departments conduct solar radiation data collection programs;
2. Determine what variables are recorded, the frequency of measurement, and the purpose of the data collection;
3. Indicate availability of data to other users; and
4. Discuss a variety of uses of the data in research.

The report includes a brief consideration of the current applications and uses of solar radiation data in Alberta. The individual projects are tabulated and discussed in part three. A summary concludes the report.

2. SOLAR RADIATION DATA COLLECTION PROGRAMS

2.1 METHODOLOGY

Information on the numerous sets of solar radiation data was compiled based on a series of telephone inquiries and in some cases, personal visits to the data gathering agencies. Information obtained included the purpose of the data collection, the length of record available, the fluxes measured, and the type of instrumentation used.

2.2 SOLAR RADIATION MEASUREMENTS

The spectrum of electromagnetic radiation can be subdivided according to the wavelength of the radiation. Radiation observed in the range of 0.15 to 3.0 um is designated to be solar radiation (Oke 1978). For measurement purposes, the solar radiation wavelengths have been subdivided into radiation fields (RF). Each field has a designated identification number as described in Table 1. Global solar radiation, PF_1, is the total incoming short wave radiation received from the whole dome of the sky on a horizontal surface. This radiation is comprised of a direct and a diffuse component. The diffuse radiation, RF_2, has been scattered by particulates in the atmosphere. Diffuse radiation represents the radiation received from the whole sky dome on a horizontal sensor which is shielded from the direct rays of the sun. Another radiation field is net all-wave radiation, RF_4. This field is the resultant flux of incoming and outgoing radiation.

With the use of optical filters mounted on the sensors, further subdivision of the radiation field is possible. Ultraviolet radiation can be measured separately, for example. Photosynthetically active radiation (PAR), the radiation utilized by vegetation, can be measured independently of total solar radiation. However, in Alberta the majority of projects measure incoming solar radiation (RF_1) only.

In Canada, incoming solar radiation is routinely measured by the Atmospheric Environment Service at a network of 53 stations throughout the country. This network is dense compared to world standards, but large

Table 1. Radiation Field Designations.

RADIATION FIELD	WMO[a]	DEFINITION
RF_1 Global Solar Radiation	$K\downarrow$	The total incoming short wave solar radiation from the whole dome of the sky, received on a flat, horizontally-mounted thermopile surface.
PF_2 Sky Radiation (Diffuse)	D	The portion of the total incoming shortwave solar radiation from the whole dome of the sky received on a flat, horizontally-mounted thermopile surface which is shielded by means of a shade ring from the direct rays of the sun.
RF_3 Reflected Radiation	$K\uparrow$	The portion of the total incoming shortwave solar radiation from the whole dome of the sky which has been reflected from the earth's surface and received on a flat, horizontally-mounted thermopile surface.
PF_4 Net Padiation	Q^*	The resultant flux of incoming (solar and atmospheric radiation) and outgoing (terrestrial and reflected solar radiation) radiation components measured through a flat horizontally-mounted thermopile.
RF_5 Incoming Net Radiation	$Q\downarrow$	Net flux of downward total radiation (solar and atmospheric) from the whole dome of the sky received on a flat, horizontally-mounted sensor.

Continued ....

Table 1. Concluded.

PF_6	Outgoing Net Radiation	$Q\uparrow$	Net flux of upward total radiation (reflected solar and terrestrial) received through a flat horizontally-mounted sensor.
PF_7	Daylight Illumination		The total visible (0.51 um to 0.61 um) radiation from the whole dome of the sky, received on a horizontal surface.
PF_8		I	The portion of the total incoming solar radiation at normal incidence to the sensor (direct beam only).

[a] World Meteorological Organization designations.
Source: Canada. Department of Environment. Atmospheric Environment Service 1979.

areas of Canada are not covered by these stations. In addition to these sites, many other studies are conducted which augment the sparse radiation data. For example, AES compiles data summaries of computer estimated values of global, direct, and diffuse solar radiation for approximately 100 locations in Canada.

2.3 USES OF SOLAR RADIATION DATA IN RESEARCH

Solar radiation studies have fallen traditionally in the domain of the atmospheric sciences. Data derived from these studies are now employed worldwide in a variety of research endeavours including air pollution, engineering, and agricultural studies. A number of applications of solar radiation data in research are presented.

Solar radiation is an integral component of air quality research, especially relating to radiation-induced photochemistry and the resultant secondary pollutants. Several gaseous pollutants react to ultraviolet radiation and dissociate the gaseous compound. For example, under solar radiation nitrogen dioxide (NO_2) breaks down to nitric oxide (NO) and atomic oxygen (O). The atomic oxygen reacts with the oxygen molecule to form ozone (O_3). The NO_2 may also react with reactive hydrocarbons to yield peroxyacetyl nitrates (PAN). Both products can cause eye and throat irritation (Peake and Sandhu 1983).

Atmospheric pollutants, both gaseous and fine particulates, interact with solar radiation and act as optical filters. The resultant radiation flux may be altered spectrally and in magnitude. Air pollutants filter out shorter wavelengths preferentially. For example, photosynthetically active radiation (PAR) and ultraviolet radiation may be attenuated by up to 40% by elevated pollutant layers in the atmosphere (Oke 1978).

Further research concerning atmospheric radiation and air quality concentrates on the effect of increased pollutants on the thermal structure of the atmosphere. Early work by Atwater (1971) shows pollutants can cause elevated inversions largely due to increased thermal or longwave radiation from the pollutants. Later studies show that the daytime presence of radiatively active pollutants increases the vertical

stability of the atmosphere by reducing the atmospheric temperature gradients. Consequently, higher concentrations of pollutants are sustained since dispersion is inhibited (Atwater 1975).

Other noted effects of increased atmospheric pollutants include a reduction of received radiation at the ground surface. After comparing rural and urban radiation data, Peterson and Stoffel (1980) report a 3% reduction in solar radiation in the urban setting. The greatest depletion of solar radiation has been measured at high latitude cities (Peterson et al. 1978). After detailed modelling simulations, Viskanta and Weirich (1978) conclude that the feedback between radiatively active pollutants and surface temperatures is greatest for night-time simulations with snow-covered ground. Both factors (snow and high latitudes) make radiation in air quality research important to Alberta.

The use of solar energy as a power source is increasing as the need for alternate energy sources persists. Passive solar heating depends for its success on the receipt of sufficient solar energy. The standard reported values of incoming solar radiation at a given location are for a horizontal surface. Tabulated values are insufficient to calculate the radiant loading, and thus potential energy, on the walls of a building. Consequently, research in the field of building design and the design of efficient heating and cooling systems concentrates on measuring fluxes on tilted surfaces with different orientations to the solar beam.

Three applications of solar radiation data are currently being researched by Alberta Agriculture throughout the province. First, the data are used in the verification of crop productivity models. Second, it is an important input parameter in the planning of irrigation schedules. Third, solar radiation data are being used to assess the potential of using solar energy in the process of grain drying.

A variety of research activities incorporating solar radiation data have been discussed. The following section briefly outlines the individual data collection programs in Alberta.

3. DISCUSSION OF DATA COLLECTION PROGRAMS

Solar radiation data have at one time been collected at 40 locations in Alberta (Figure 1) for a large range of projects. The projects vary regarding the length of time data were collected and the fluxes measured. Table 2 shows the data collection projects arranged by the agency responsible for the data.

3.1 ALBERTA AGRICULTURE

3.1.1 Farm Irrigation Services

Incoming solar radiation is used to plan irrigation schedules. Data are collected over a five-month period, from May to September. The study started in 1980.

An Eppley pyranometer measures hourly values. Readings are made once a day of an integrated 24-hour value. Weekend values are an assigned average of a three-day total. The data are in hardcopy form only. Reliability of these data is high as the equipment is regularly calibrated against Canadian Department of Agriculture instruments.

3.1.2 Systems Engineering Branch

This branch has conducted short-term, limited measurements at several locations to investigate the solar radiation potential for grain drying. The last measurement program was in 1980. The pyranometer was zeroed periodically, and only initially calibrated. The data were recorded on cassette tape; however, these data are not readily available.

3.2 ALBERTA ENVIRONMENT

3.2.1 Earth Sciences Division, Hydrogeology Branch

The division measured incoming solar radiation on the peak of Turtle Mountain in the Crowsnest Pass. A Licor pyranometer was used and integrated hourly values of the radiation flux were recorded on cassette tape. Data are archived in tabular form on computer tape. This

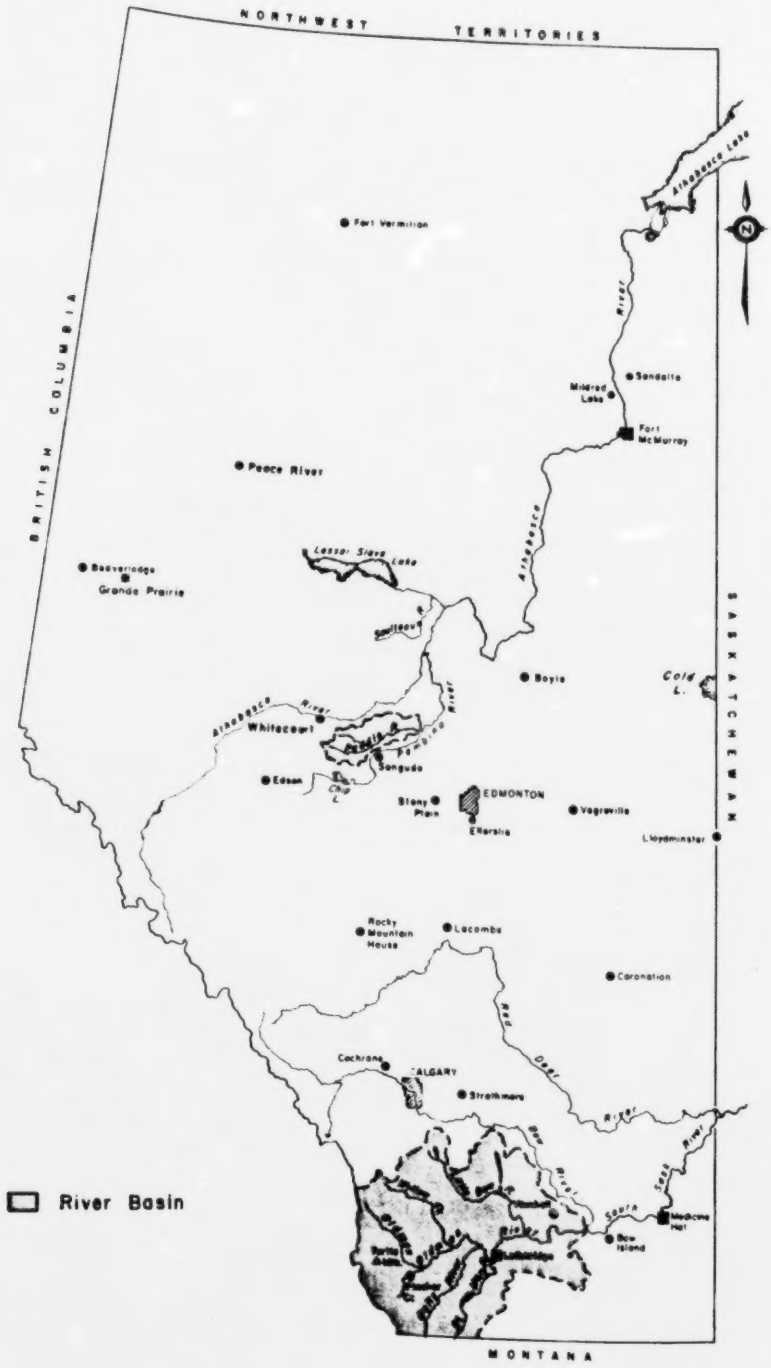

Figure 1. Locations of radiation data measurements.

Table 2. Data collection programs in Alberta.

Agency	Instrumentation Location	Parameters Measured	Purpose/Description	Data Handling/Storage
Alberta Agriculture Farm Irrigation Services	Bow Island Strathmore Lethbridge	RF_1	Data for an irrigation scheduling computer model. Summer data only. Daily readings. 1980 to present.	Manual reading, hardcopy only.
Alberta Agriculture Systems Engineering Branch	Medicine Hat Sanqudo, Boyle Lloydminster	RF_1	Data base for research into utilization of solar energy for grain drying purposes. Projects are short-term special studies. 1980.	Recorded on cassette tape, not readily available.
Alberta Environment Earth Sciences Division, Hydrogeology Branch	Turtle Mountain Crowsnest Pass	RF_1	Data base used with other meteorological parameters to monitor meteorological environment on mountain top. 1983 to 1984.	Recorded on cassette tape, stored on computer tape.
Alberta Environment Technical Services Division, River Forecast Centre	Oldman River Basin Paddle River Basin	RF_1	Utilize solar radiation data in models to calculate snowmelt rates. 1984 ongoing.	Transmitted in real time to River Forecast Centre, archived on computer tape.
Alberta Environment Pollution Control Division, Air Quality Branch	Ellerslie	RF_1, RF_4 albedo	Part of full meteorological measurement program. 1978 to present.	Recorded electronically, stored on computer tape, summaries available.
	Oxbridge Place Edmonton	RF_1, UV	Research program to monitor radiation values in urban location. 1977 to 1981.	Recorded on printer, not archived.

continued . . .

Table 2. Continued.

Agency	Instrumentation Location	Parameters Measured	Purpose/Description	Data Handling/Storage
Alberta Environment Research Management Division	Mildred Lake	RF_1, RF_4	Data base for ongoing research including snow surveys, acoustic radar studies, plume chemistry studies. 1976 to 1981.	Recorded on strip chart, summarized in hardcopy only.
	Sandalta Site	RF_1	Ongoing research for acid deposition programme. 1983 to present, April to September.	Recorded electronically, stored on computer discs, summaries available.
Alberta Research Council, Solar and Wind Energy Research Program	Edson Rocky Mtn. House Pincher Creek Lethbridge Coronation Ellerslie Fort McMurray	RF_1, RF_2, RF_4	Monitor solar and wind energy resources throughout the province to assess their potential as alternate energy sources. 1980 to 1985.	Recorded electronically on cassette tape, archived on computer tape. Summary reports will be available shortly.
Government of Canada Atmospheric Environment Service	Beaverlodge Stony Plain Suffield Lethbridge Marmot Basin - discontinued	RF_1, RF_1, RF_2, RF_4, RF_1, RF_4, RF_1	Part of national network of meteorological stations Beaverlodge - 1960 onwards Stony Plain - 1966 onwards Suffield - 1959 onwards Lethbridge - 1952 to 1964 - 1972 onwards	Recorded data submitted monthly to AES offices, published as Monthly Radiation Summary, summaries available on microfiche.
	Calgary, Cold Lake Coronation, Ft. McMurray Grande Prairie Lethbridge Medicine Hat Peace River Red Deer Rocky Mtn. House Fort Vermilion Whitecourt	RF_1 RF_2 RF_1 on sloped surfaces	Includes computer generated values based on routinely measured meteorological variables. Data summaries 1967 to 1976.	Statistical summaries of data to be published in booklet form.

Table 2. Continued.

Agency	Instrumentation Location	Parameters Measured	Purpose/Description	Data Handling/Storage
Government of Canada Agriculture Canada	Beaverlodge	RF_1, RF_2, RF_3, RF_4, PAR, RF_5	Agriculture research in a northern Alberta location. late 1981 onwards.	Recorded continuously on data logger, archived on computer tape in Ottawa.
Government of Canada Agriculture Canada	Lethbridge Vauxhall	RF_1	Used in evaporation studies from small lakes and crops. Long-term record dating back to 1969.	Recorded on weekly charts and extracted manually. Daily totals of incoming radiation are archived on computer file in Lethbridge
Government of Canada Agriculture Canada	Lacombe Beaverlodge Lethbridge Vegreville Ellerslie	PAR Photon flux	Research program designed to investigate relationships between herbicide efficacy and crop damage due to environmental factors. May to September, 1983 ongoing.	Recorded on cassette tape in the field. Archived on computer tape at University of Alberta.
University of Alberta Department of Forest Science	Salteaux River	RF_1, RF_4	Research project to derive methods of estimating evaporative losses in a peat dominated forest. Summer data only. 1983 to 1984	Recorded electronically on cassette tape. Archived on computer tape at University of Alberta. Raw data.
University of Alberta Geography Department	Ellerslie	RF_1	Conducts full set of meteorological measurements. Data base for research programs. 1982 onwards.	Recorded electronically, stored on computer tape in tabulated format.
University of Alberta Department of Mechanical Engineering	Ellerslie	RF_1, on inclined surfaces behind glass.	Passive solar energy research for building design and heating strategies. September to April, 1980 onwards.	Recorded electronically. stored in computer tape. Internal reports only.
	Edmonton, University of Alberta Campus	RFg RF_1 - filtered RF_1 - total UV, thermal radiation	Research on heating, ventilation, and air conditioning constraints on building design. 1976 to 1983.	Recorded manually, stored on computer disc, unsummarized.

continued . . .

Table 2. Concluded.

Agency	Instrumentation Location	Parameters Measured	Purpose/Description	Data Handling/Storage
University of Calgary Department of Geography	Calgary	RF_1, RF_4	Part of Calgary Weather Station 1968 onwards.	Some data on paper punch tape. Some data published in Solar Energy Atlas of Alberta. Sorted on computer file now.
University of Calgary Department of Physics	Cochrane	RF_1 and thermal radiation (3.0 um to 80.0 um)	Research to develop on all sky scanning radiometer for all wave lengths. 1983 onwards.	Telemetered to Calgary. Stored as hardcopy. As yet not totally processed.

short-term record, operated all year, from June 1983 to June 1984, provided all-season data. Solar radiation was one component of a set of meteorological parameters measured to understand the mountaintop environment.

3.2.2 Technical Services Division, River Forecast Centre

The division is beginning a solar radiation measurement program. The purpose is to use the radiation values to calculate snowmelt rates. These results are to be compared to actual melt rates as determined from snow pillows.

Two pyranometers are used, one facing upward, the other downward. A cone limits the field of view of the downward facing instrument to ensure accuracy. Albedo values can be calculated. Integrated hourly values will be relayed in real time to the River Forecast Centre's computer to be archived on computer tape. The planned locations for operation in 1984 are the Oldman River Basin and the Paddle River Basin.

3.2.3 Pollution Control Division, Air Quality Branch

The Air Quality Branch operates a meteorological station at Ellerslie, south of Edmonton. This facility provides the most complete and continuous record of incoming solar radiation, reflected solar radiation, and net radiation. The instruments are regularly calibrated and maintained. The data are archived on computer tape from 1978 onwards. Tabulated summaries are available.

3.2.4 Research Management Division

Incoming solar radiation and net radiation were recorded for approximately five years (1976 to 1981) at the Mildred Lake site, northwest of Fort McMurray. Sensors were situated in a clearing; however, at low sun angles the trees partly shaded the sensors. Preliminary analyses of the data revealed a discrepancy in the hour

parameter. The RF_1 data can be corrected; the RF_4 data are unreliable. Data are available in hardcopy only.

A second data set was obtained for a 4 year period with a pyranometer and ultraviolet radiometer situated on the roof of the Oxbridge Place building in downtown Edmonton. The sensors were not well attended and the data are of questionable quality. The data have not been archived and are available in hardcopy only.

There is a short-term record of incoming solar radiation for the Sandalta site, northeast of Fort McMurray, starting in April 1983. Data are recorded on cassette tape and tabulated summaries are available. These data are part of a full air quality research program, including concurrent measurements of ozone, sulphur dioxide, and the oxides of nitrogen. The radiation data will contribute to atmospheric transformation calculations and atmospheric attenuation characteristics resulting from the plumes of two oil sands refining plants.

3.3 ALBERTA RESEARCH COUNCIL

3.3.1 Solar and Wind Energy Research Program (SWERP)

The program presently monitors solar and wind energy resources at seven sites with the main purpose of assessing the potential of these resources in Alberta. The data will be used to: (1) supplement the present limited data sources from Alberta; (2) aid in the design of alternate energy systems; (3) verify or develop solar energy prediction models; and (4) provide a basis for further research.

The radiation measurements, including solar, net, and diffuse fluxes, are part of a full set of meteorological parameters. Air temperature, wind speed, and direction are measured. The solar radiation flux is measured on all six faces of a cube at a height of 1.2 metres.

The data are recorded electronically on a cassette tape which is retrieved monthly. The data are subsequently fed into the computer and tabulated summaries and graphs are produced. Data will be archived on the University of Alberta computer.

The final site at Fort McMurray has been operating since October 1983 completing the seven stations. Monitoring will continue until March 1985.

3.4 GOVERNMENT OF CANADA

3.4.1 Agriculture Canada

The Northern Agricultural Research Station at Beaverlodge, Alberta, is the most complete radiation station in Western Canada. Studies there provide base line data of the radiation balance for the Peace River district in northern Alberta. The solar, net, diffuse, and photosynthetically active radiation data will be used to assess the relationship of crops to their energy requirements, and the energy availability. A second research site has been operating at Fort Vermilion since the summer of 1984.

Beaverlodge is one of the few stations to include an evaluation of albedo and it is one of two stations to record photosynthetically active radiation on a routine basis. The data are recorded continuously on an integrating data logger and archived in Ottawa, Ontario, on the central Agriculture Canada computer.

3.4.2 Atmospheric Environment Service

Data are routinely collected at five locations. At each site daily calibration and time checks are performed. The charts are forwarded to the AES offices in Downsview, Ontario, where they are summarized and published in the Monthly Radiation Summary. Hourly and monthly radiation totals are tabulated. The period of record varies for each station.

Additional data are available on microfiche in the Western Regional Office of AES in Edmonton, starting in 1980. Data are presented in greater detail including hourly means, extremes, standard deviations, and percentage frequencies of daily radiation.

Supplementing the RF_1 records of the 5 stations are computer-generated data available from 12 other locations. Direct,

diffuse, and net radiation fluxes are generated from routinely measured meteorological parameters. Data summaries have been produced for daily and hourly average solar radiation for each month for the period 1967 to 1976. These data are used to fill in gaps in the measured solar radiation data base, simulate solar radiation of various sloped surfaces for various azimuths and provide statistical summaries of the data.

3.5 UNIVERSITY OF ALBERTA

3.5.1 Department of Forest Science

This research project was designed to investigate methods of estimating the evaporative losses of organic soils in northern Alberta. A full set of meteorological parameters was measured including total solar radiation and net radiation. The measurement period extended from July to September 1983 and continued the next year. Hourly totals are recorded on cassette tape and then processed and stored on computer tape.

3.5.2 Department of Geography

A university climatological research station operates at Ellerslie, south of Edmonton, where an integrating data logger records solar radiation continuously. A calibrated Eppley pyranometer is used. Peliable data exist from September 1982 onwards. Prior to this date, poor recorders and equipment were used and the data are suspect. The data are archived on computer tape and are available for use.

3.5.3 Department of Mechanical Engineering

A research project started in 1980 to address passive solar energy design questions. The measurement program operates from September to April. Some equipment breakdowns were experienced, and most good data begin in 1981. Incoming solar radiation is measured on vertical, horizontal, and 75^{o} to horizontal surfaces, and behind window glass. Some data are published as internal reports only. The data are reported as hourly average fluxes, and are stored on computer tape at the University of Alberta.

Further research is conducted with a sensor located on a university campus rooftop. An Eppley pyreheliometer, measuring direct beam radiation only, is mounted and outfitted with three filters to conduct spectral measurements. There are also limited longwave radiance measurements made with an Eppley pyrgeometer. This research was initiated to investigate heating, ventilation, and air conditioning problems of buildings. Data collection was started in 1976 and finished in 1983. Full analysis of the data is not complete; however, data are archived with other projects on computer disks.

3.6 UNIVERSITY OF CALGARY

3.6.1 Department of Geography

The Calgary weather station is operated by personnel from the Department of Geography. The data are used in a variety of meteorological research projects. Both solar and net radiation have been gathered for 15 years. During this period, the instrumentation and recording equipment have been upgraded. Earlier data were recorded on paper tape, more recent data (1982 onwards) are recorded on cassette tape. Values include one-half-hour totals and 12-hour totals. These data have been used to produce the Solar Energy Atlas of Alberta (Nkemdirim 1979).

3.6.2 Department of Physics

Research is underway to develop an automatic all-sky scanning radiometer. The research site is Cochrane, Alberta. At this site, solar radiation and thermal radiation (3.0 um to 80.0 um) for the whole sky are sensed in one scan. In this way, the effect on the angular dependence of sky radiance values of cloud cover, pollution build-up, or tropospheric temperature changes is minimized (Coombes and Harrison 1982).

4. SUMMARY

The projects presently underway in Alberta illustrate the varied applications of solar radiation data. This report has identified agencies currently collecting data. Thirty-six locations are cited for solar radiation measurements. Both the University of Calgary and the University of Alberta support solar radiation research. Within the provincial government two departments, Agriculture and Environment, conduct measurement programs. The Alberta Research Council carries out solar radiation research under the Solar and Wind Energy Research Program. In the federal government, the Atmospheric Environment Service and Agriculture Canada record radiation values at a number of sites.

The radiation flux recorded at 34 of the sites is incoming solar radiation (RF_1). The second most frequently measured flux is net radiation (RF_4) at 17 sites. For more specific research projects, photosynthetically active radiation is measured at two sites; ultraviolet, incoming net and direct beam radiation are recorded at a single site each.

The frequency of measurement varies for individual projects depending on the purpose of the data collection. It may vary from year-round hourly values to summer only values averaged weekly.

The main purpose of these data collection programs is research into the application of solar energy as an energy source for engineering and agricultural purposes. The network operated by the Atmospheric Environment Service routinely monitors solar radiation values as part of a national network of sites.

The availability of data differs from agency to agency. Those measurement programs using computerized data loggers generally have data archived on computer and thus are easily retrieved. Interested persons may contact the individual agency directly for further information and access to the data. The work of researchers in the province would be enhanced with greater co-ordination and dissemination of data and project results.

The greatest shortcoming of the numerous research and monitoring programs involving solar radiation is that the data sets are site specific, due to the control exerted by the surface temperature and albedo. This fact limits the usefulness of the data for comparative studies. Future research projects should be designed to include multiple data sets, involving, for instance, a rural and urban location. Different wavebands of radiation may also be compared. For example, in a study of radiation induced photochemistry, it would be necessary to measure simultaneously ultraviolet and total solar radiation.

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6. APPENDIX

6.1 AGENCIES/DEPARTMENTS CONTACTED

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